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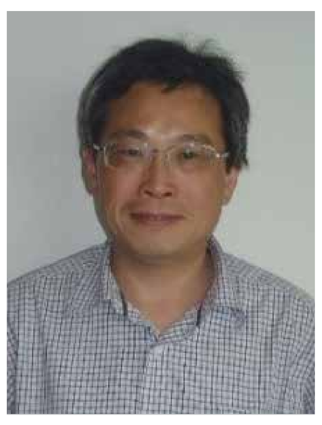
Petrophysical characterisation of the Cambrian and Neoproterozoic successions in the Officer Basin



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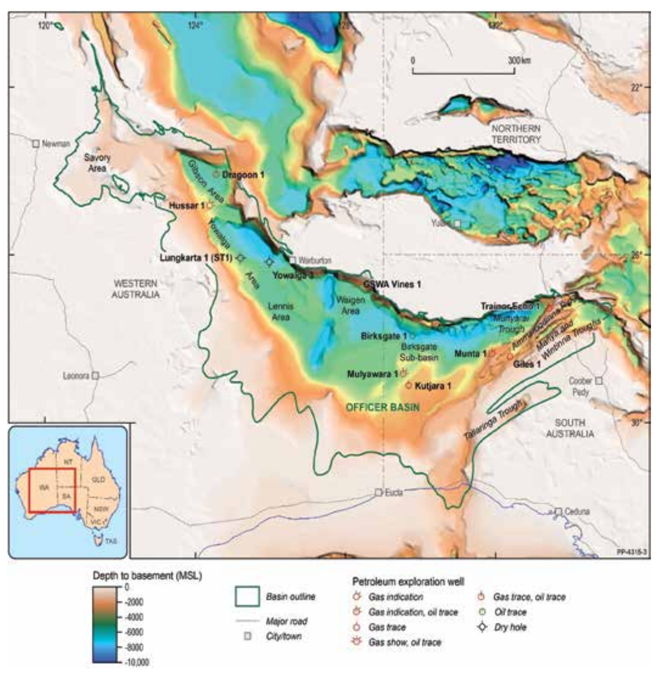
Petrophysical characterisation of the Neoproterozoic and Cambrian successions in the Officer Basin

Liuqi Wang, Adam H. E. Bailey, Lidena K. Carr, Dianne S. Edwards, Kamal Khider, Jade Anderson, Christopher J. Boreham, Chris Southby, David N. Dewhurst, Lionel Esteban, Stuart Munday, Paul A. Henson

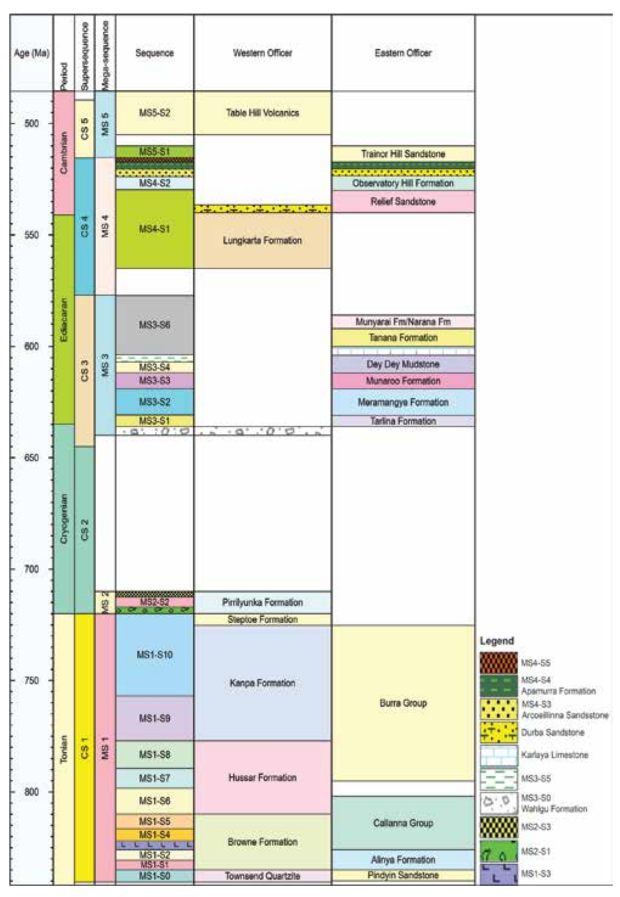
Introduction

The Neoproterozoic–Paleozoic Officer Basin is a frontier basin that spans across South Australia to Western Australia. As one part of Geoscience Australia's Exploring for the Future program, petrophysical properties were derived to characterise potential reservoirs in the Neoproterozoic and Cambrian successions using both laboratory testing and well log interpretation in six selected wells.

Reservoir characterisation was conducted using the chemostratigraphic mega-sequences and sequences defined in Munday *et al.* (2021)



Major tectonic sub-divisions, wells and hydrocarbon shows in the Officer Basin, superimposed on OZ Seebase (Geognostics 2021).



Stratigraphy of the Neoproterozoic and Cambrian successions in the Officer Basin.

Laboratory testing

- Forty-one samples of various rock types were analysed and tested to derive the petrophysical properties of conventional, tight and shale reservoir rocks (Bailey *et al.* 2021).
- Laboratory testing provides the relationships among the various laboratory measured permeability measurements of different reservoir types: air permeability, Klinkenberg corrected permeability, and nano-scale permeability.

Average petrophysical properties of the various rock types in the Officer Basin.

Period	Reservoir	Total porosity (%)	Gas (nitrogen) porosity (%)	Gas permeability (mD)	Klinkenberg corrected permeability (mD)	Nano-scale permeability (mD)	Grain density (g/cm^3)
Cambrian	Conventional	26.52	22.15	3.96	2.73648		2.69
	Tight	10.38	2.71	0.00378	0.00043		2.728
	Shale	10.35	2.90	0.00779	0.00124	0.00138	2.75
Neoproterozoic	Conventional	17.79	15.55	7.20886	5.63172		2.696
	Tight	6.0	1.96	0.00953	0.00166	0.00047	2.744
	Shale	4.13	0.61	0.00318	0.00038	0.00059	2.792

Well log interpretation

Conventional interpretation

- Volume fraction of shale (Vshale) was derived from gamma ray/lithology logs.
- Effective and total porosity were interpreted from sonic slowness and neutron–density.

Self-organising map (SOM)

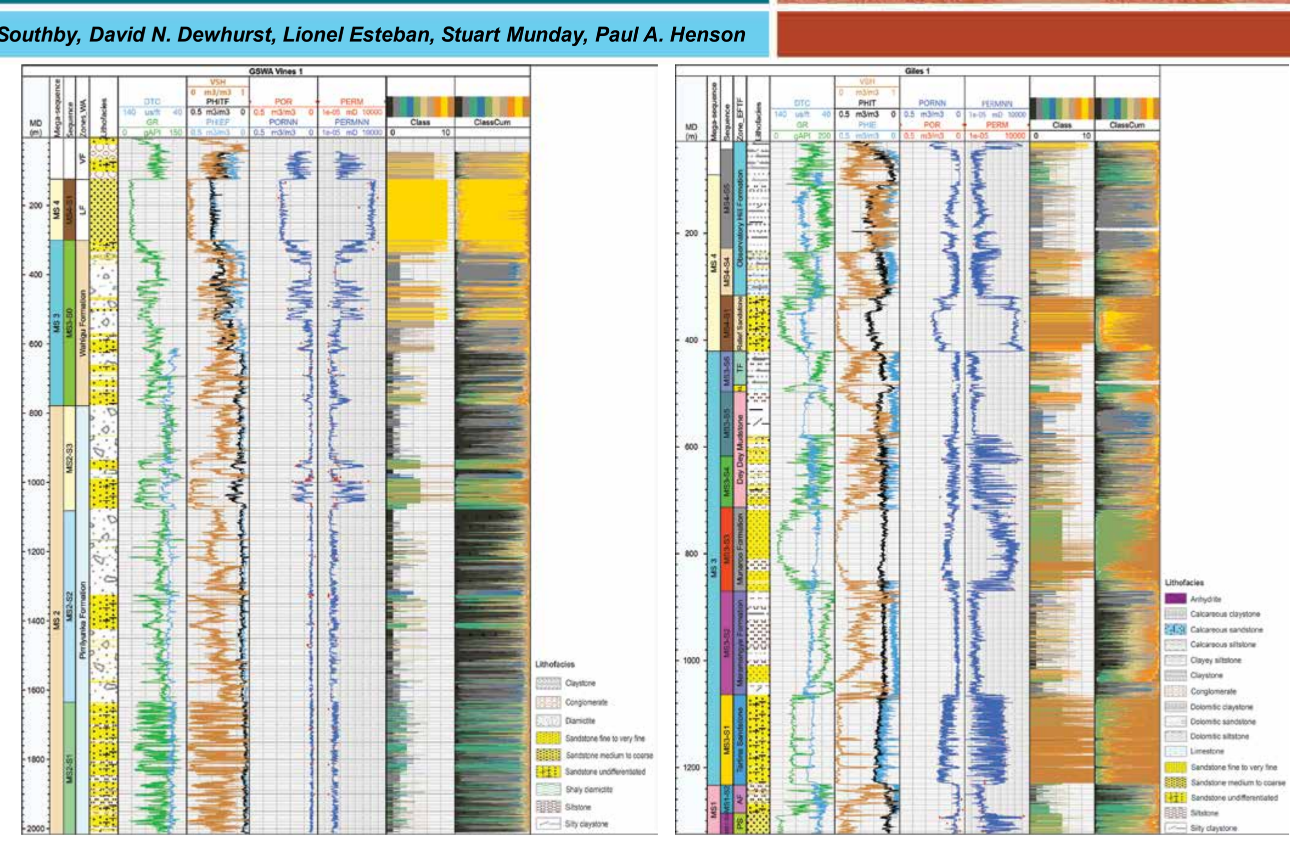
- Petrophysical group/class index was derived from well logs and conventional interpretations using SOM clustering.
- The cumulated probability profiles help lithostratigraphic correlation.

Interpretation with artificial neural networks (ANNs)

- Porosity and permeability were approximated from well logs, conventional interpretations and petrophysical class index.
- Hyperparameters were optimised by performing sensitivity analysis using errors and correlation coefficient.
- ANN performs the permeability interpretation significantly better than linear regression.

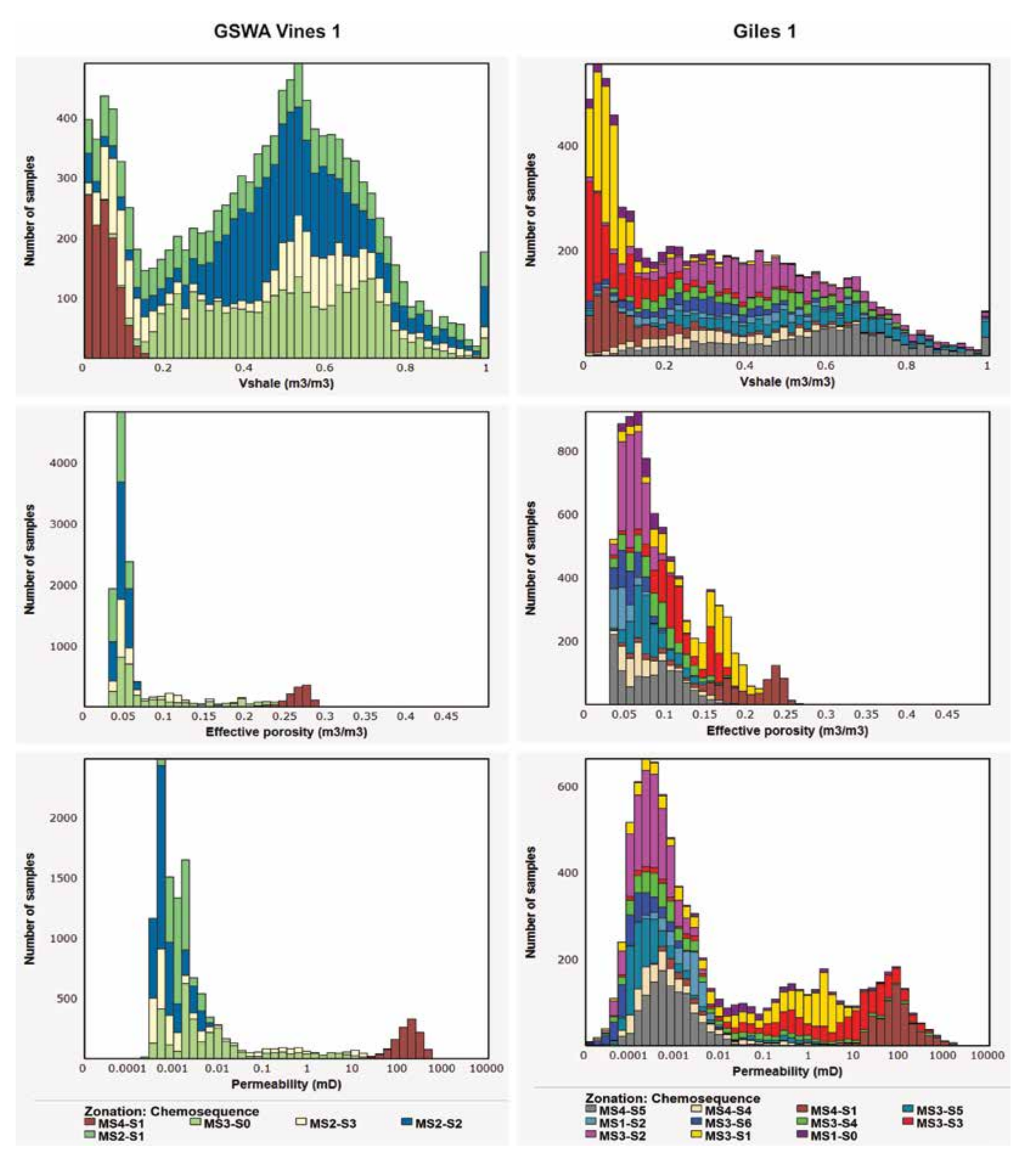
Key references

- *Bailey, A., Wang, L., Dewhurst, D. N., Esteban, L., Kager, S., Monmusson, L., Jarrett, A. J. M., and Henson, P. (2021). Exploring for the Future – petrophysical and geomechanical testing program data release, Officer Basin, Australia. Record 2021/28. Geoscience Australia, Canberra. doi:10.11636/Record.2021.028.*
- *Munday, S., Edwards, D.S, Chandra, J., Forbes, A., Riley, D., Wang, L., Anderson, J., Grosjean, E., Bailey, A., and Boreham, C.J. (2021). Defining a chemostratigraphic framework for the Officer Basin. Record 2022/07. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2022.007.*



Well profiles of GSWA Vines 1 and Gile s 1. Column 1: measured depth (MD, m); Columns 2 and 3: mega-sequences and sequences defined by Munday et al. (2021); Column 4: lithostratigraphic units (LF: Lungkarta Formation; and VF: Vines Formation); Column 5: lithological descriptions from composite log; Column 6: gamma ray (GR, gAPI) and compressional wave slowness (DTC, μs/ft) logs; Column 7: interpreted Vshale (VSH, m3/m3), effective porosity (PHIEF, m3/m3) and total porosity (PHITF, m3/m3) from conventional interpretations; Column 8: neural network interpreted and laboratory measured porosity (PORNN and POR, m3/m3); Column 9: neural network interpreted and laboratory measured permeability (PERMNN and PERM, mD); Column 10: rock class from SOM clustering (Class); Column 11: cumulative probability curves of classes from SOM clustering (ClassCum).

Petrophysical characterisation



Distributions of interpreted Vshale, porosity and permeability in different chemostratigraphic sequences in GSWA Vines 1 and Giles 1.

Ratios of conventional and tight reservoirs (RCRG and RTRG), average interpreted porosity and geometric mean of permeability of conventional and tight reservoirs in each mega-sequence (MS) in the six selected Officer Basin wells. Conventional, tight and shale reservoirs are defined according to Vshale, effective porosity and permeability in the six selected wells.

MS	Well	RCRG (N/G)	RTRG (N/G)	Conventional reservoir		Tight reservoir	
				Porosity (m^3/m^3)	Permeability (mD)	Porosity (m^3/m^3)	Permeability (mD)
MS1	Yowalga 3	0.08	0.5294	0.1594	4.75779	0.055	0.00084
	Giles 1	0.0534	0.7799	0.1235	29.3907	0.057	0.01307
	Hussar 1	0.195	0.5584	0.1602	3.9192	0.0635	0.00182
MS2	GSWA Vines 1	0.0392	0.5353	0.1314	1.02196	0.0477	0.00139
MS3	Giles 1	0.2946	0.3243	0.151	3.85303	0.0755	0.00088
	Birksgate 1	0.0175	0.7124	0.1454	0.34101	0.0736	0.00166
	GSWA Vines 1	0.1607	0.4239	0.1972	1.1655	0.0805	0.00525
	Hussar 1	0.1955	0.4511	0.2174	15.6723	0.077	0.00167
	Munta 1	0.0034	0.9424	0.1058	0.79241	0.0558	0.01102
MS4	Giles 1	0.3243	0.5022	0.2006	52.7401	0.0698	0.00089
	Birksgate 1	0.3473	0.4577	0.184	8.4987	0.086	0.00758
	GSWA Vines 1	1	0	0.2638	152.613		
	Munta 1	0.6885	0.2654	0.2206	103.675	0.104	0.00159

Conclusions

- Mega-Sequences 1, 2 and 3 host predominantly the tight reservoirs.
- Mega-Sequence 4 has both the conventional and tight reservoirs.
- Shales have favourable sealing capacity.

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